

Stony Brook University

sPHENIX

TPC-only K_S^0 reconstruction

Xudong Yu

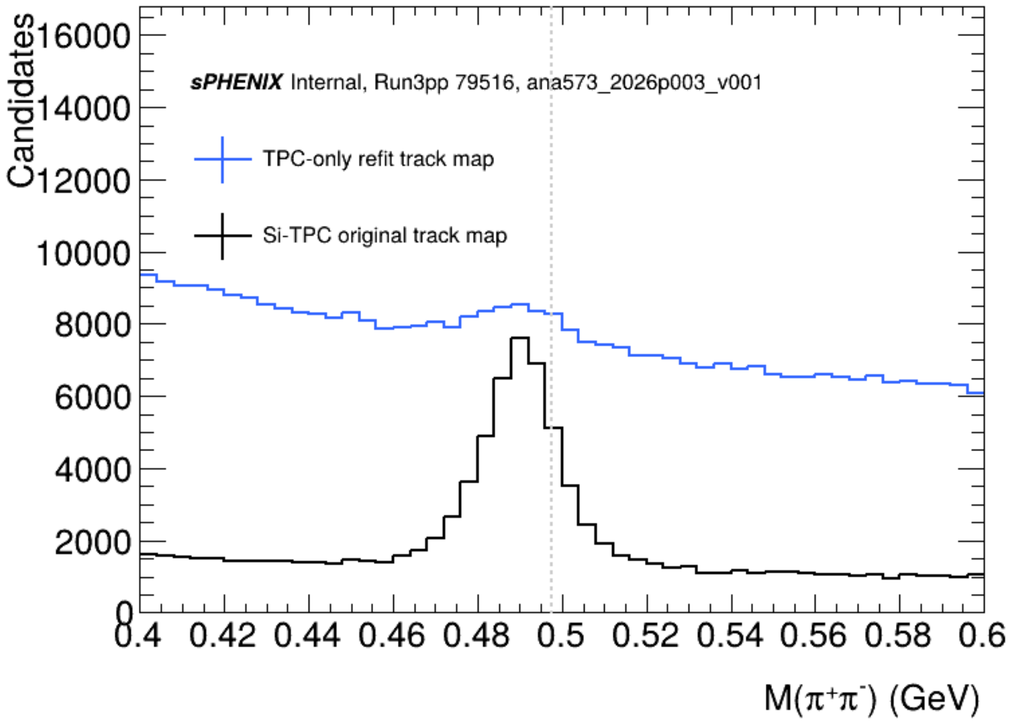
10/27/2026

Motivation

- ➔ Kshort reconstruction using poly seed shows very clear signal peak with low background rate (See Yuri and Mariia's slides)
- ➔ Poly seeds and clusters are converted to standard sPHENIX tracking format, and finally fitted by ACTS
- ➔ The motivation of this study is to check if Kshort reconstructed from poly seed and ACTS are consistent
- ➔ My TPC-only acts fit workflow
  - ❖ Create a new SvtxTrackSeedContainer which contains track seed associated with svtx track in the SvtxTrackMap after TrackCleaner
    - ▸ Before TrackCleaner, one TPC seed can be matched with multiple silicon seed, so there will be duplicate tpc seed
  - ❖ TPC seed cluster positions have been corrected by crossing, but the initial track position z0 is not corrected by crossing. This causes acts fit fail
  - ❖ I do crossing correction on the initial seed z0 before acts fit
    - ▸ correctedZ0 = TpcClusterZCrossingCorrection::correctZ(tpcSeed->get_Z0(), side, crossing);
    - ▸ tpcSeed->set_Z0(correctedZ0);
  - ❖ Use filtered and crossing corrected SvtxTrackSeedContainer as input for acts fit, and run it with forceTpcOnlyFit(true)
  - ❖ Use output SvtxTrackMap_TpcOnly as input for KFParticle, and run it with useTPConlyTracks(true)

TPC-only track refit vs Si-TPC orignal track fit

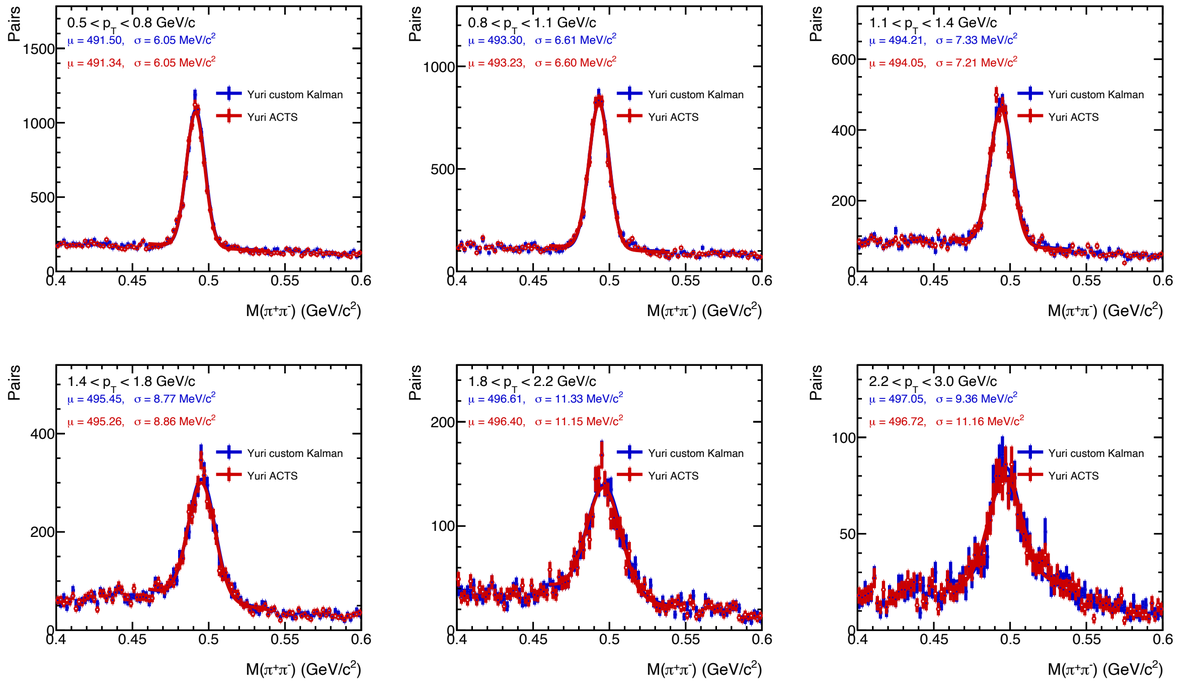
- ➔ Run 79516, 1000 segments, ana573_2026p003_v001
- ➔ Track pT > 0.2 GeV
- ➔ More background and less signal in refit track map than original track map



Yuri's workflow vs Acts + KFParticle

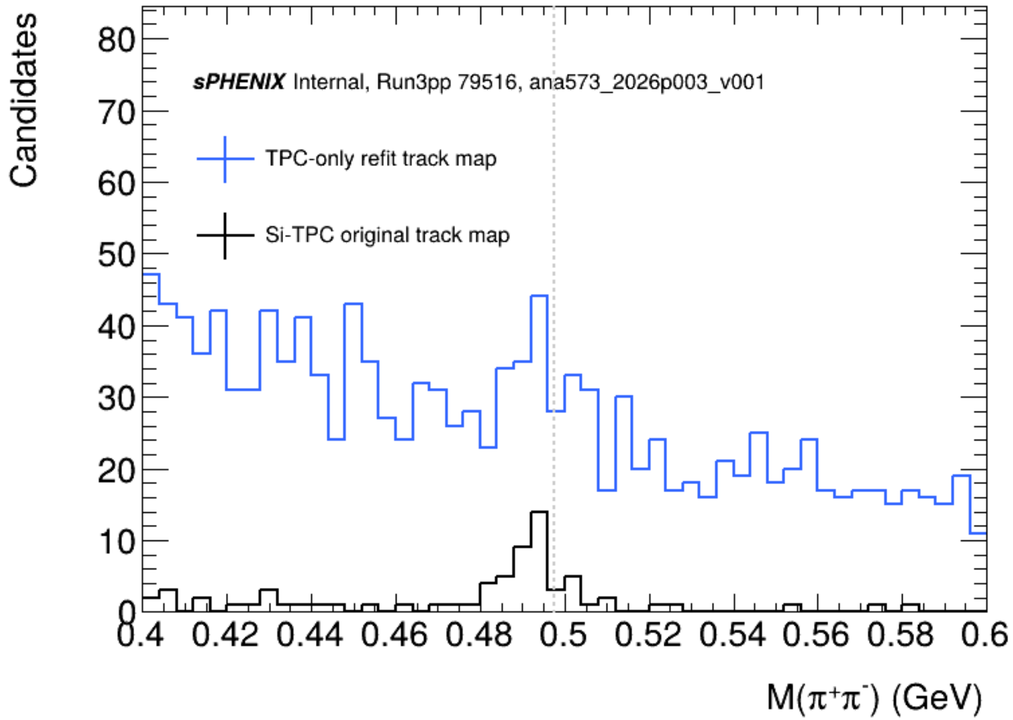
➔ Much less signals in acts + KFParticle, confusion

Poly seed + Yuri's TpcHadronReco module + cut03 (see backup)



Tried both Kalman & ACTS in Yuri's module
No obvious difference, consistent with Yuri's finding

Acts fit tracks + KFParticle + equivalent cuts

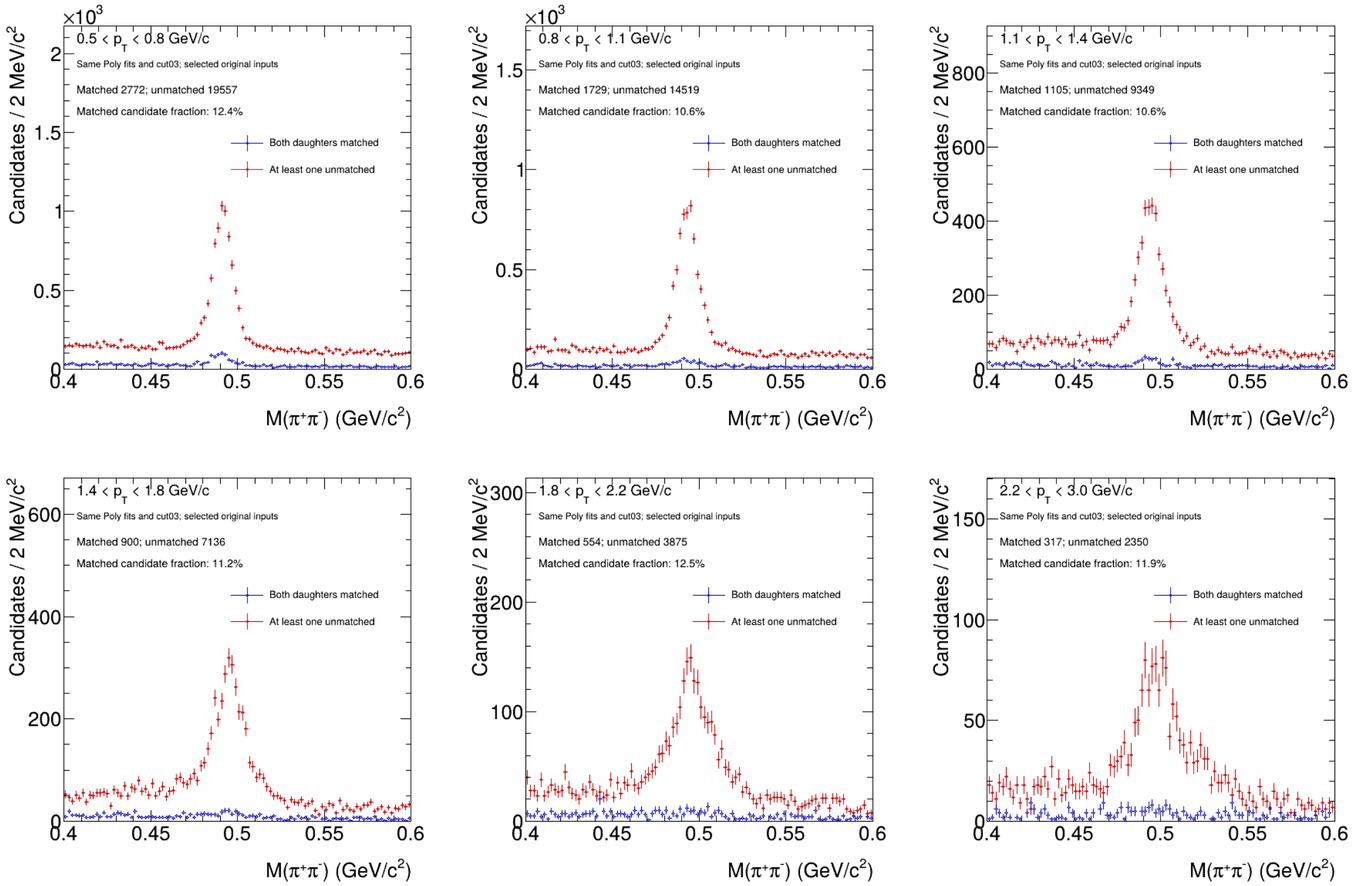


Diagnostic

➔ Match tracks used by kshort reconstructions among poly seed map, original map and refit map

- ❖ Using unique TPC seed ID or source ID

➔ Most of poly seeds do not exist in track maps, so we loose most of Kshort signals



Red: at least one track unmatched
Blue: both tracks matched

Tracking problem

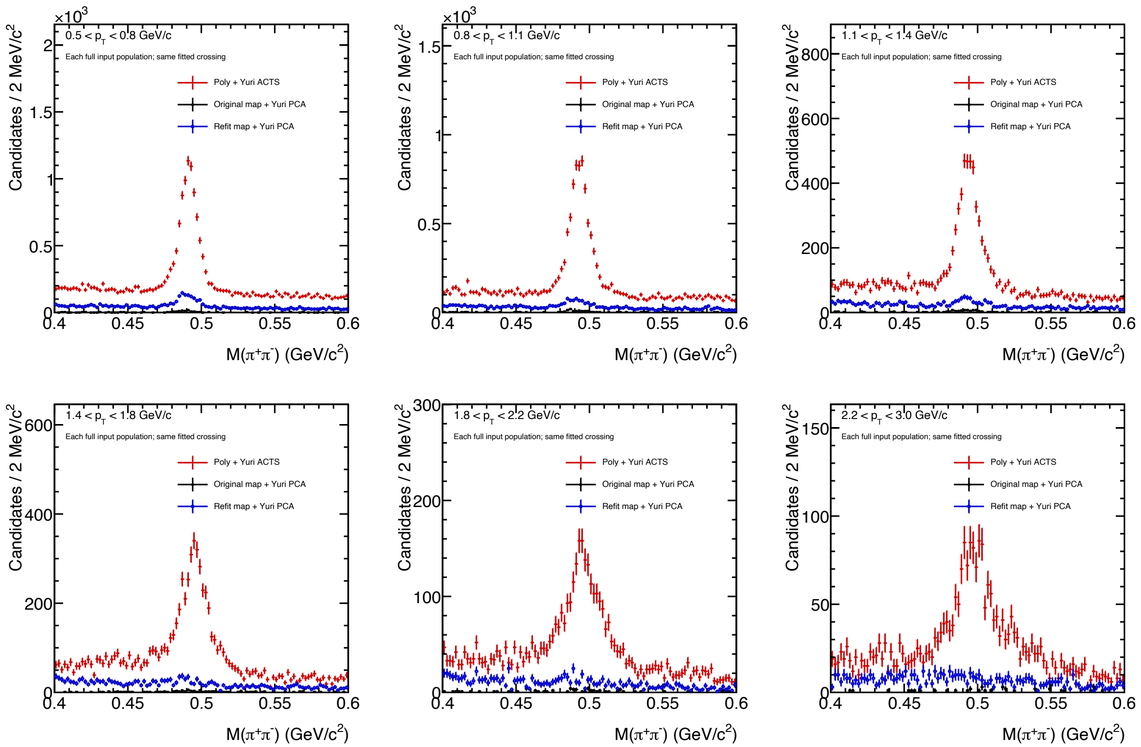
➔ Decorrelate tracking and KFP, so I use the same Yuri's TpcHadronReco module in Kshort reconstruction

➔ We try three different track maps:

- ❖ Poly seed + Yuri's acts refit in TpcHadronReco module (reference)
- ❖ Poly seed + PHActs original track map (first acts fit)
- ❖ Poly seed + PHActs refit track map (second acts fit, tpc-only)

➔ Confirm that main difference comes from tracking

Red: Poly seed + Yuri's acts refit
Black: Poly seed + PHActs first
Blue: Poly seed + PHActs second (tpc-only)



PHActs problem

➔ Two ways to investigate why most of seeds do not pass tracking

- ❖ Method 1: Run large data sample, calculate survival rate at every stages
- ❖ Method 2: Run few Kshort events and check why they are rejected by PHActs event by event

➔ Method 1 check points: converter & matching, first acts fit, track cleaner, filter & second acts refit

➔ Conclusion: First acts fit loose most of Kshort signals

Stage	Kshort candidates	Fractions
Poly seed (reference)	64163	100%
Converter & matching	63162	100%
First acts fit	21539	33.57%
Track Cleaner	21005	32.74%
Filter & second acts refit	21005	32.74%

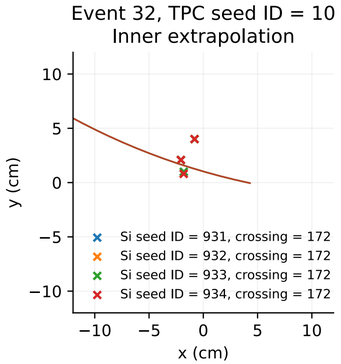
Event-by-event check

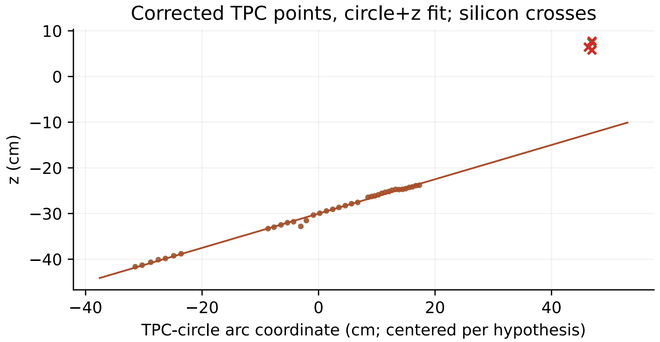
- ➔ Method2: I investigate 10 kshort events (20 tracks) which pass TPC standalone reconstruction but fail in full tracking framework
- ➔ Only 1 Kshort (both two tracks) pass first acts fit, 9 fail
- ➔ Only 6 tracks pass first acts fit, 14 tracks fail
- ➔ 14 failed tracks: 7 tpc-only tracks, 7 silicon-tpc matched tracks
- ➔ 7 tpc-only tracks: poly seed crossing different from acts fit crossing
  - ❖ In PHActsTrkFitter, crossing for TPC-only tracks are set to 0 which is acceptable for CA seeding because crossing is unknown for TPC-only tracks
  - ❖ In poly seeding, poly seed has been assigned crossing
  - ❖ After using poly crossing for TPC-only tracks in the acts fit and correct initial z0 by crossing, all 7 failed tpc-only tracks recover
  - ❖ Draft PR: 4505 (CASeeding workflow is unchanged)
- ➔ 7 silicon-tpc matched tracks
  - ❖ If only fit to the corresponding tpc seed, all success
  - ❖ Failure could be due to imperfect silicon-tpc matching, for example misalignment (see event displays in the next slides)

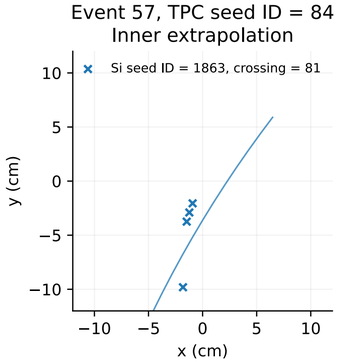
Event	TPC seed ID	Matched silicon seeds (count)	TPC-only input	Poly crossing	First-fit crossing	First-fit output
32	10	4	No	172	SHRT_MAX	No
32	14	1	No	172	172	No
43	77	0	Yes	311	0	No
43	78	0	Yes	311	0	No
44	59	0	Yes	263	0	No
44	60	0	Yes	263	0	No
57	84	1	No	81	SHRT_MAX	No
57	94	0	Yes	81	0	Yes (1)
79	159	0	Yes	158	0	No
79	168	3	No	158	134, 158	No
124	161	8	No	394	394	Yes (2)
124	192	4	No	394	394	No
125	139	8	No	182	182	Yes (2)
125	174	5	No	182	182	No
147	111	0	Yes	220	0	No
147	114	0	Yes	220	0	No
172	13	5	No	39	39	Yes (4)
172	14	1	No	39	39	No
188	52	9	No	20	20	Yes (2)
188	87	0	Yes	20	0	Yes (1)

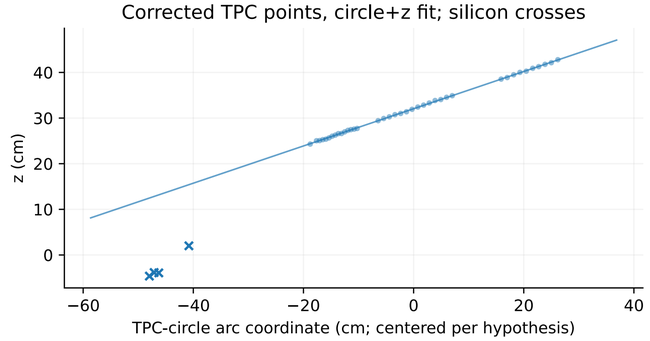
Red: TPC-only tracks
Blue: Silicon-TPC matched tracks

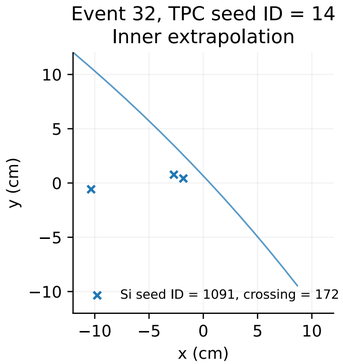
Event display

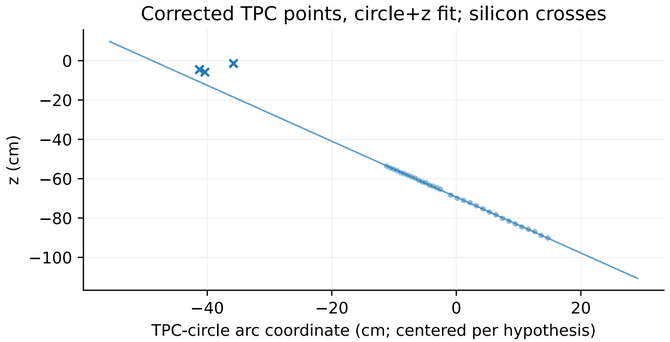


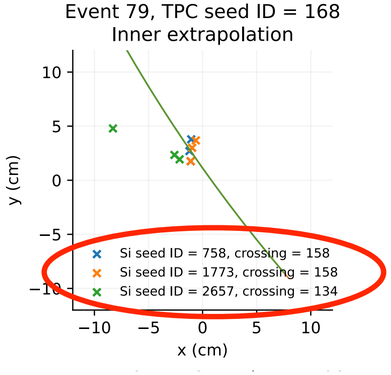


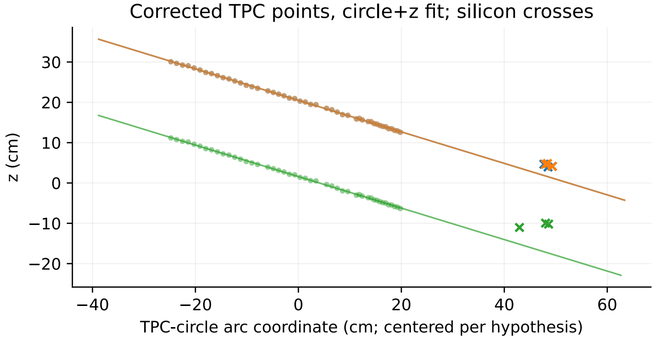












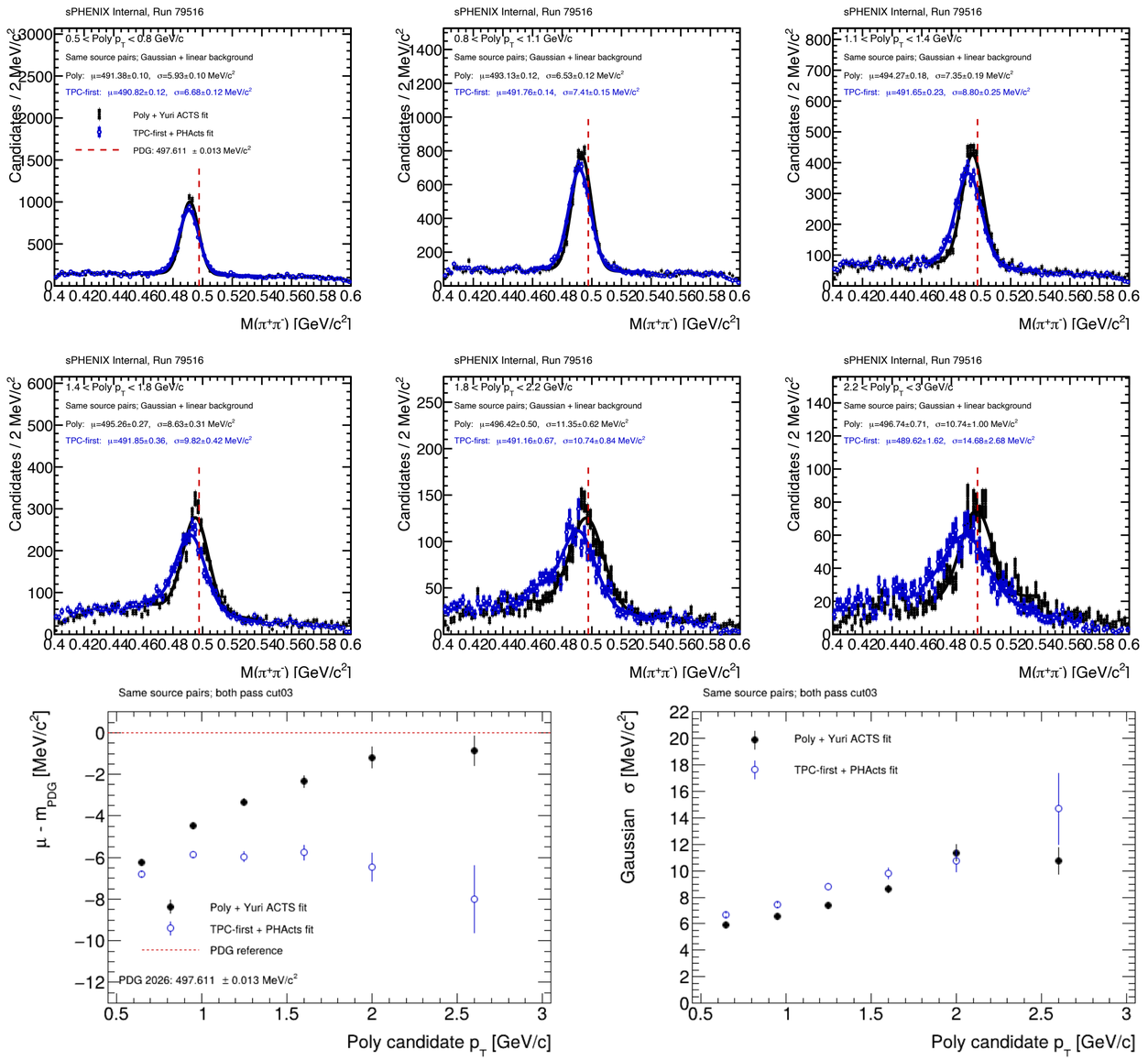
Multiple silicon seeds

Silicon-TPC misalignment will cause track mometum bias, Kshort mass shift, wrong silicon crossing assignment, quality deterioration

More event displays in backup

New TPC-only workflow

- ➔ Previous TPC-only refit workflow is affected by silicon-tpc matching
- ➔ To achieve an unbiased TPC-only track fit, I tried a new workflow
  - ❖ Convert TPC seed into Svtx seed
  - ❖ Use TPC poly seed crossing
  - ❖ Use initial z from TPC seed
- ➔ Three observations:
  - ❖ Signal yields are closed (TPC-only PHActs gives ~93% of Yuri's acts refit)
  - ❖ Low pT (~1 GeV), both fitters gives biased Kshort mass
  - ❖ Higher pT (~3 GeV), Yuri's acts refit Kshort mass converges to PDG value, while PHActs bias becomes larger and show different trend
- ➔ pT dependence are qualitatively consistent with Chenxi's simulation track momentum study
  - ❖ For low mometum, it is likely due to energy loss caused by multiple scattering in silicon. The truth momentum in the first TPC layer decreases by about 3%. Ideally, including silicon clusters with perfect alignment, this bias should be reduced
  - ❖ For high momentum, it is likely due to biased initial seed parameters. Yuri's taubin circle fitting PR will solve this



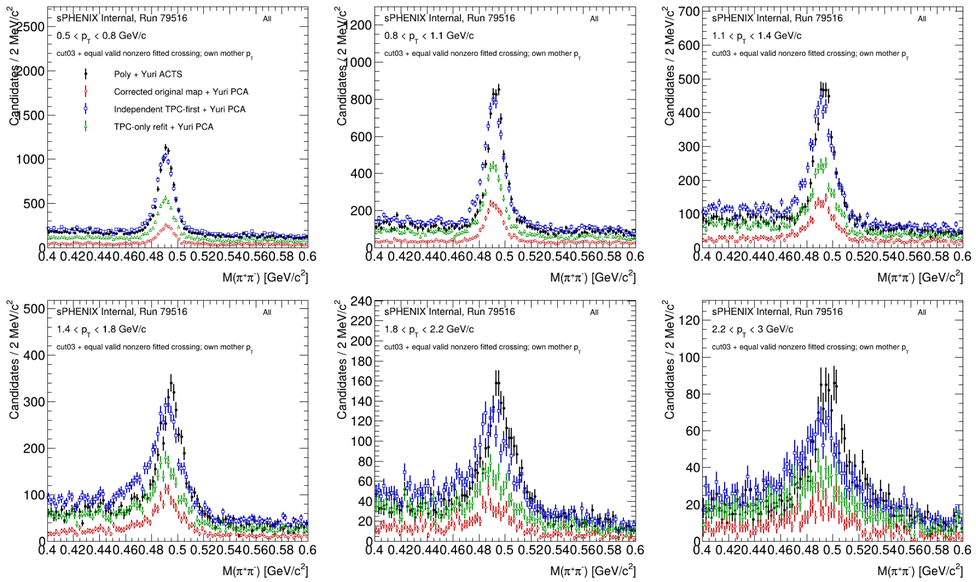
Black: Poly seed + Yuri's acts refit

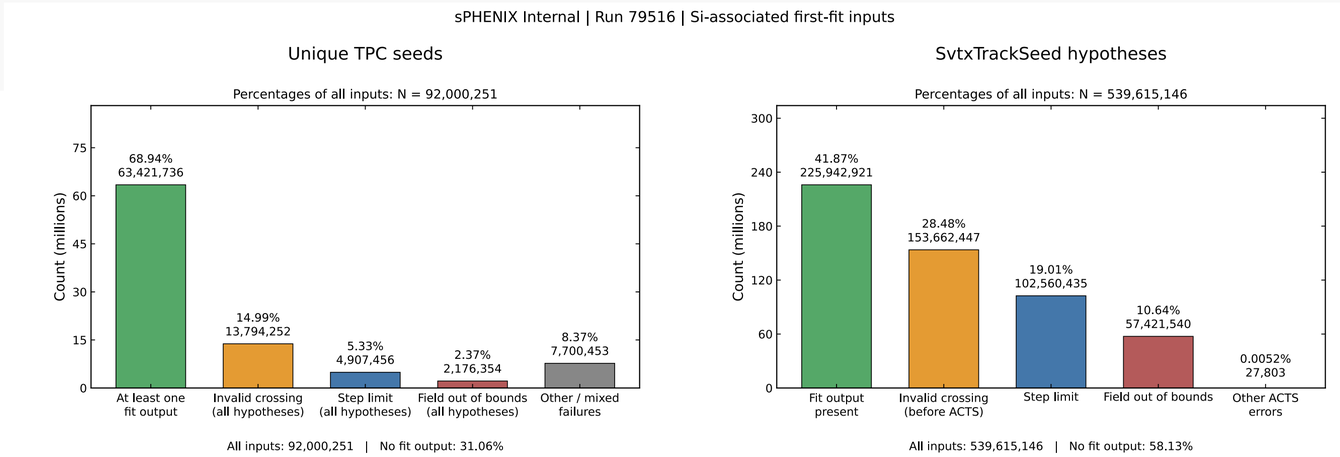
Blue: Poly seed + TPC-only PHActs (new)

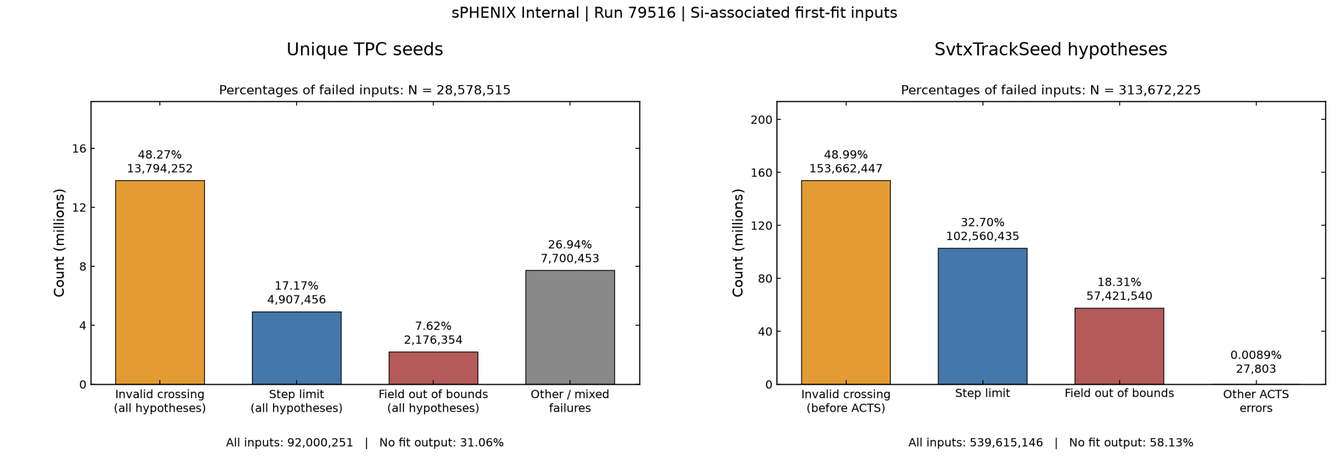
Both use Yuri's Kshort reconstruction module

Silicon-TPC acts fit failure

- I also compare Yuri's acts refit (black), TPC-only PHActs fit (Blue), Original PHActs fit (Red), and TPC-only PHActs refit (green)
  - The latter three cases are run with TPC-only crossing assignment fix
- Original PHActs fit loose many Kshort signals due to acts fit failure
- I count the various failure modes



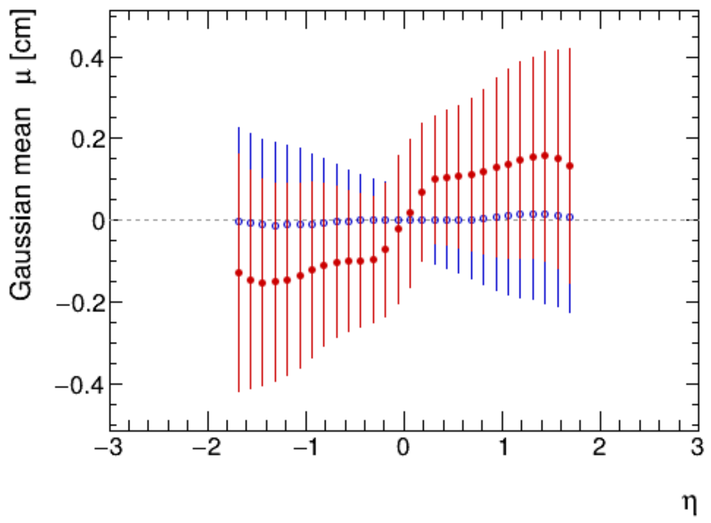


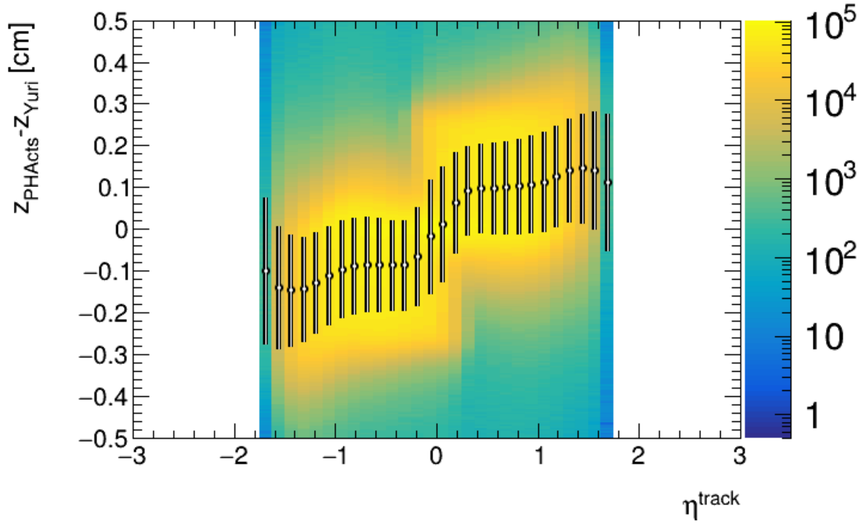


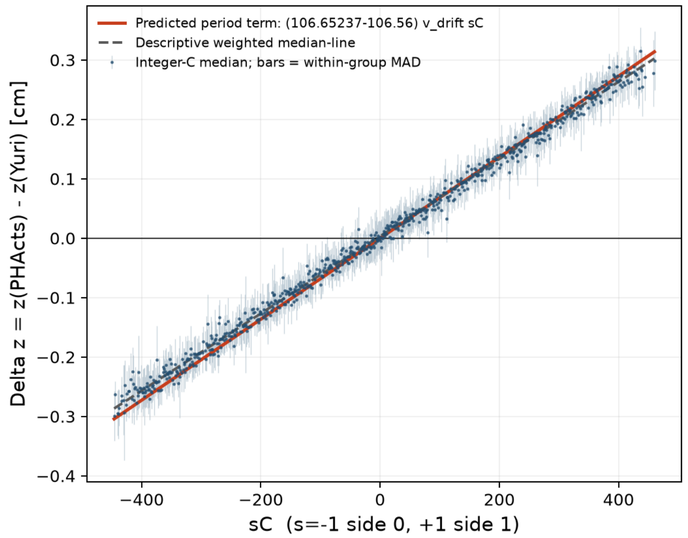
- Left: denominator is unique TPC seeds
- Right: denominator is Svtx seeds
- One TPC seed may associate with multiple Svtx seed
- For left plot, if one Silicon-TPC matching of a TPC seed succeed, the status is success
- Failure modes include Invalid crossing (SHRT_MAX), step limit, field out of bounds, etc

Time period in poly seeding

➔ In order to understand the difference between Poly seed + Yuri's Acts refit and TPC-only PHActs fit, I make a residual plots of delta-z versus eta







➔ Left: delta-z(fitted state - poly cluster) vs poly seed eta at R=42 cm; Blue for Yuri's Acts fit, Red for PHActs fit

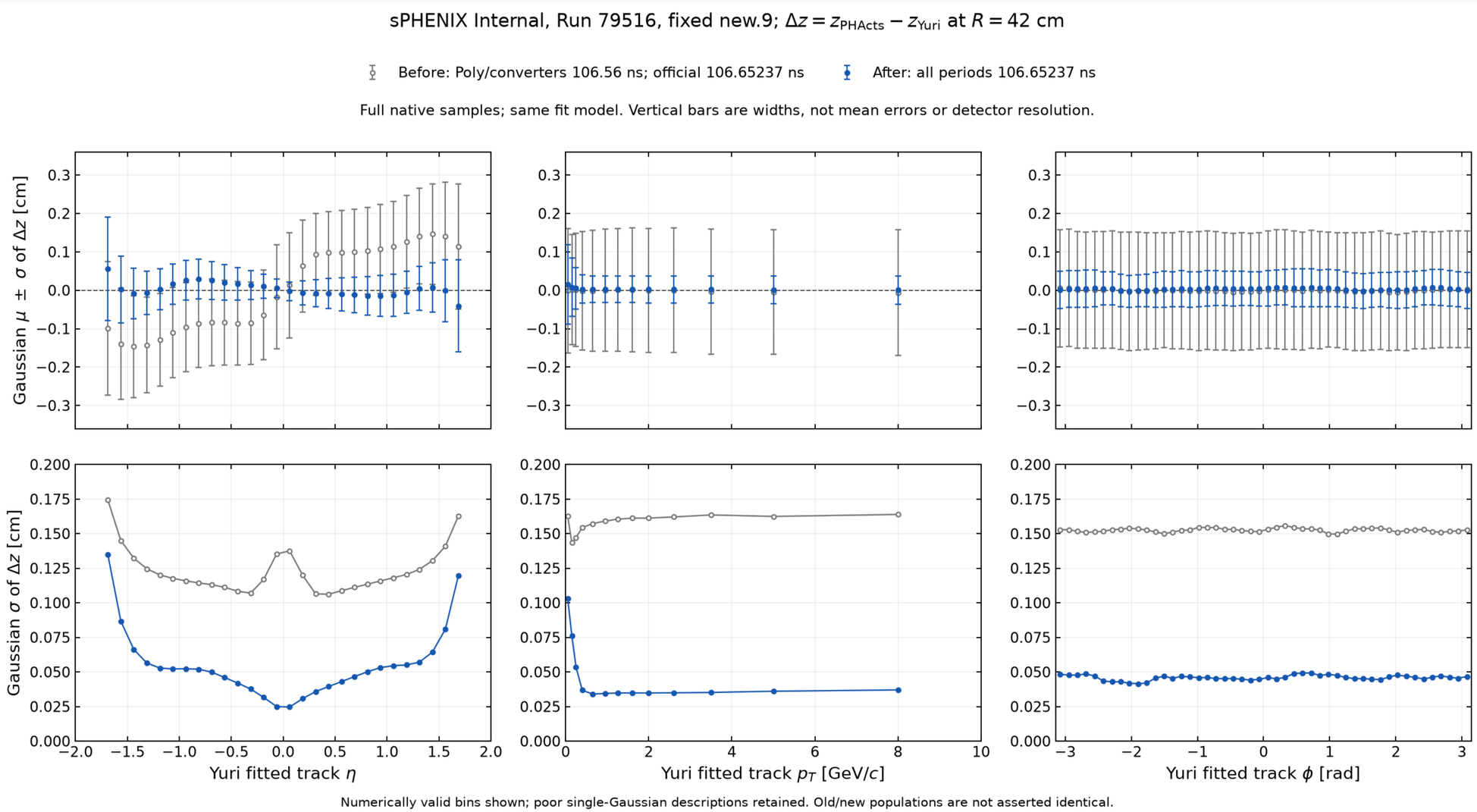
➔ Middle: delta-z(PHActs state - Yuri's Acts state) vs Yuri's fitted eta at R=42 cm

➔ Right: delta-z(PHActs state - Yuri's Acts state) vs crossing

➔ Delta-z eta dependence is due to incorrect time period setting in polyseeding workflow including TpcCrossingFinder, Tpc_PolyClusterizer, TpcPolyTrackSeedConverter and TpcPolyClusterTrkrClusterConverter

- ❖ Default value: 106.56 ns, Official value: 106.65237 ns
- ❖ Poly cluster and poly seed z positions are corrected by 106.56 ns along with crossing
- ❖ Converter do inverse crossing correction uisng 106.56 ns
- ❖ Downstream Acts fit uses 106.65237 ns to do crossing correction

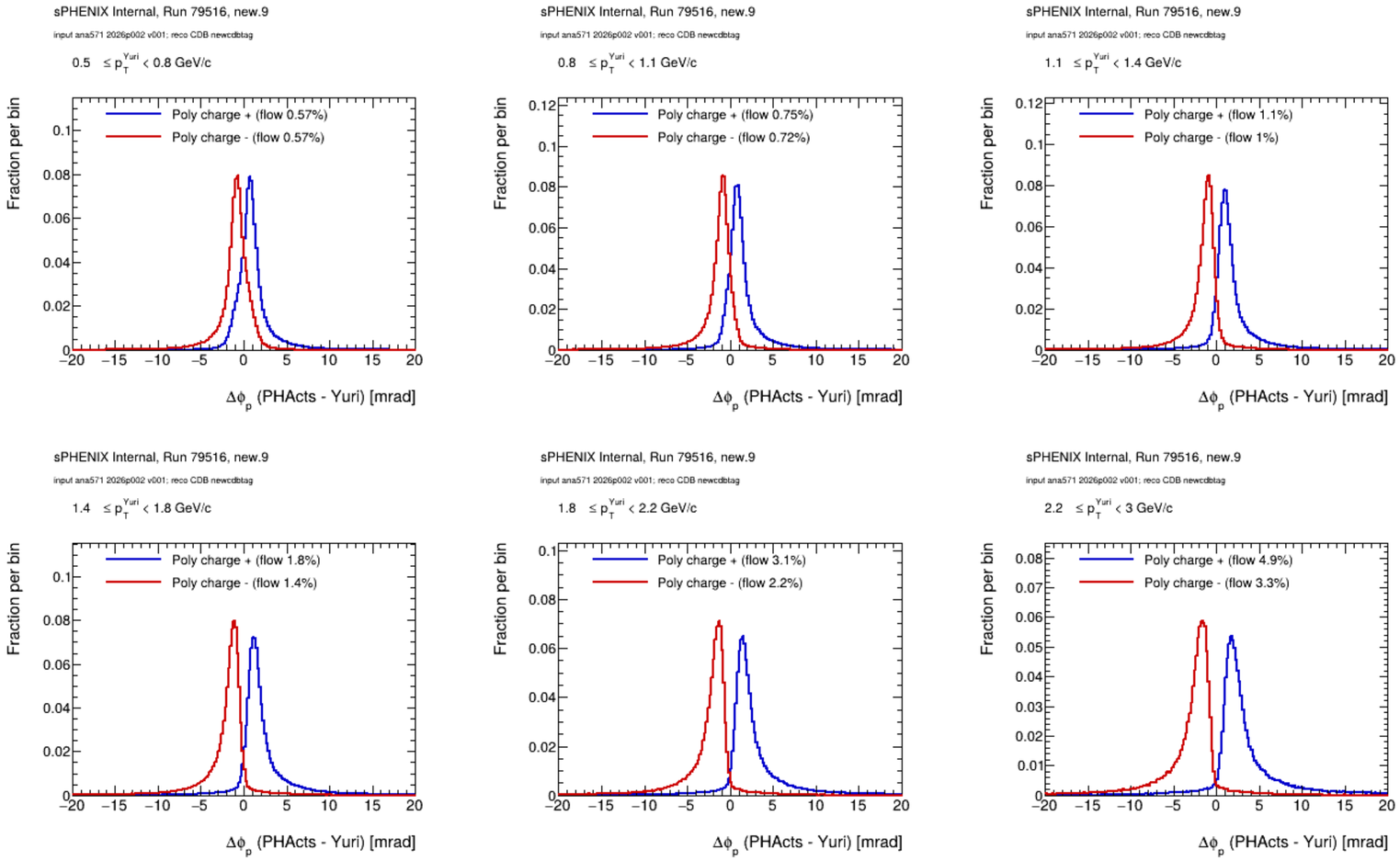
Time period in poly seeding fix



After fixing time period in poly seeding, eta-dependent delta-z problem solved
Delta-z resolution significantly improved

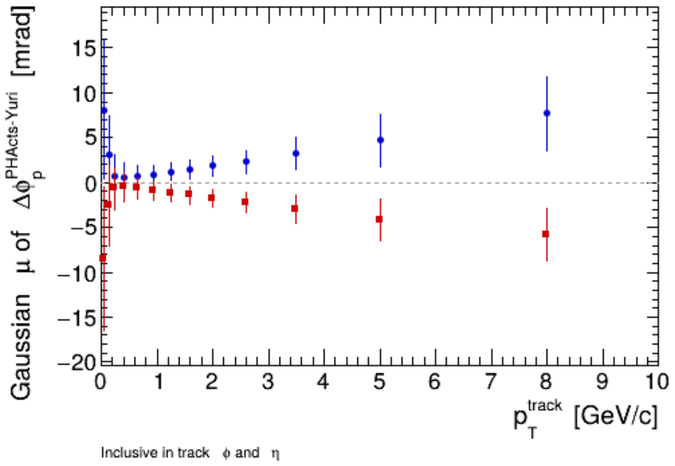
Delta-phi between PHActs and Yuri's acts fit

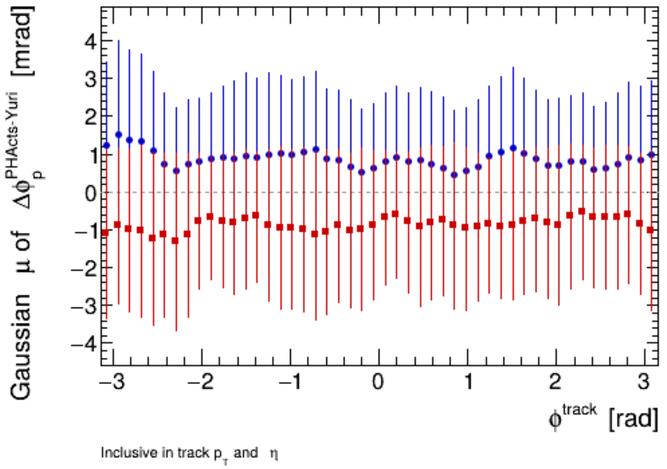
➔ Delta-phi(PHActs - Yuri) seperated by charge in different pT bin

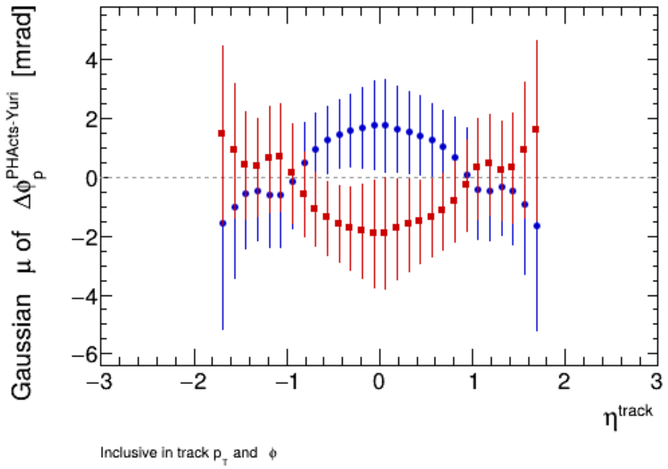


Delta-phi between PHActs and Yuri's acts fit

- ➔ Delta-phi(PHActs - Yuri) vs pT/phi/eta separated by charge
- ➔ This is before inconsistent time period, but after fixing that, delta-phi distribution is nearly unchanged
- ➔ This will be solved after Yuri's taubin fit PR



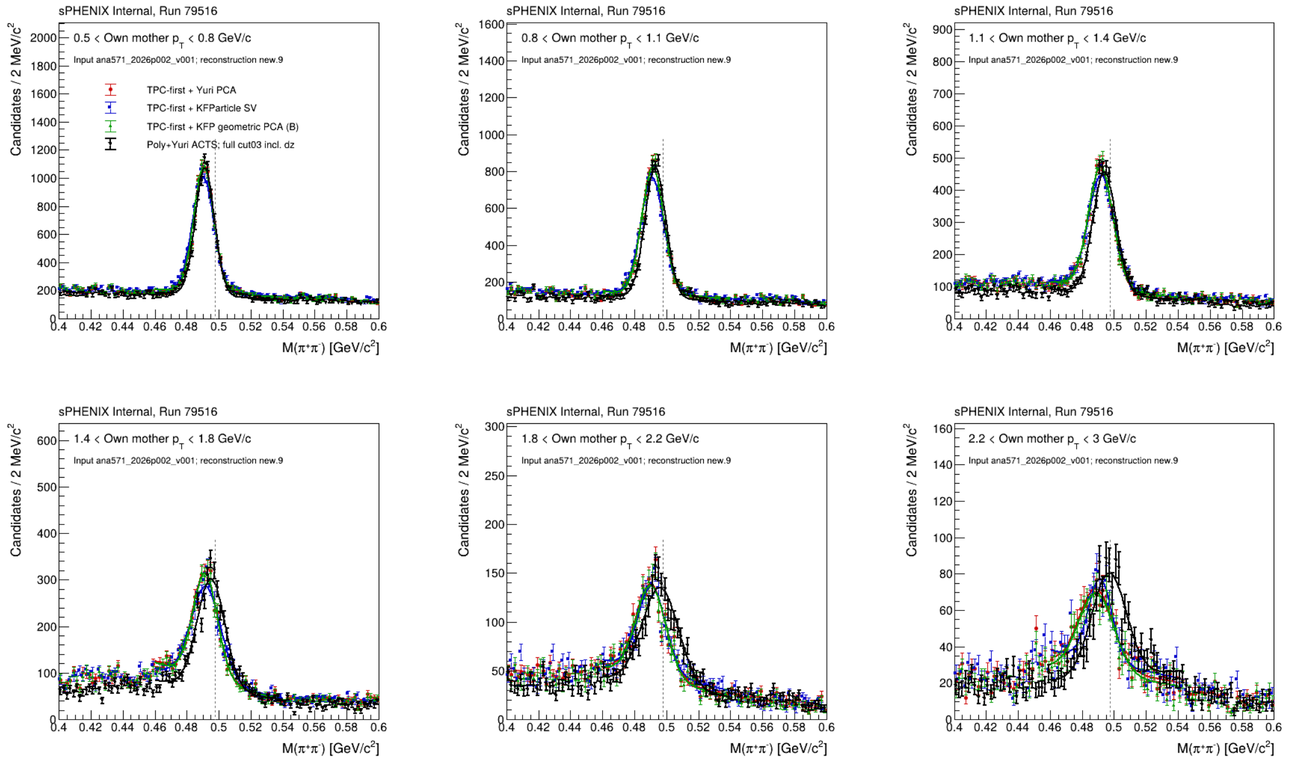




Blue: positive
Red: negative

Kshort reconstruction module comparison

- ➔ Another aspect is to compare Kshort reconstruction by KFParticle and Yuri's standalone TpcHadronReco
- ➔ Same input: TPC-only acts fit
- ➔ Three reconstruction schemes:
  - ❖ Yuri's standalone PCA (Red)
  - ❖ KFP standard common SV fit (Blue)
  - ❖ KFP + PCA (Green)
- ➔ Apply equivalent cuts for both standalone method and KFParticle
- ➔ Difference between KFP standard common SV fit and KFP + PCA is that in PCA analysis, daughters are not required to originate from the common SV.
- ➔ Difference between Yuri's standalone results and KFP + PCA results is small — mass peak positions in all pT bins are less than 0.1 MeV
- ➔ Difference between Yuri's standalone results and KFP standard common SV fit: in some specific candidates, large mass change is observed, but overall signal yields are closed (only 3.8% less in KFP standard common SV fit)

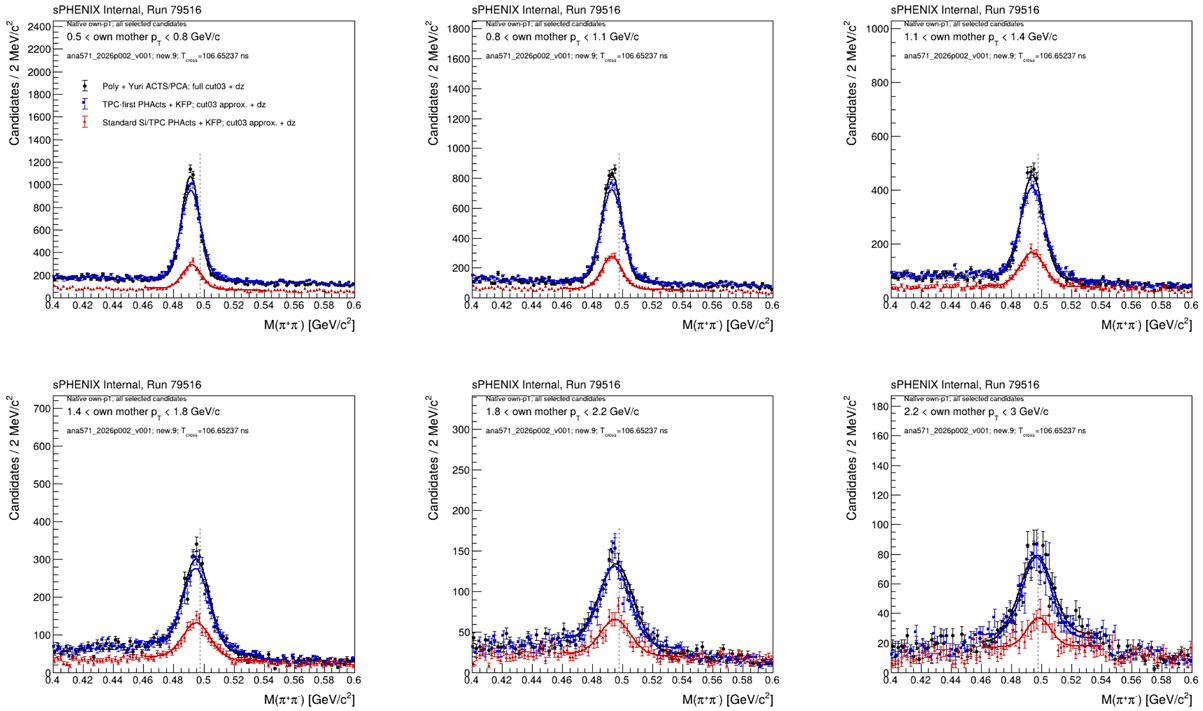


Red: TPC-only PHActs fit + Yuri's Kshort PCA reco
Blue: TPC-only PHActs fit + KFP common SV
Green: TPC-only PHActs fit + KFP no common SV
Black: Yuri's acts fit + Kshort PCA reco

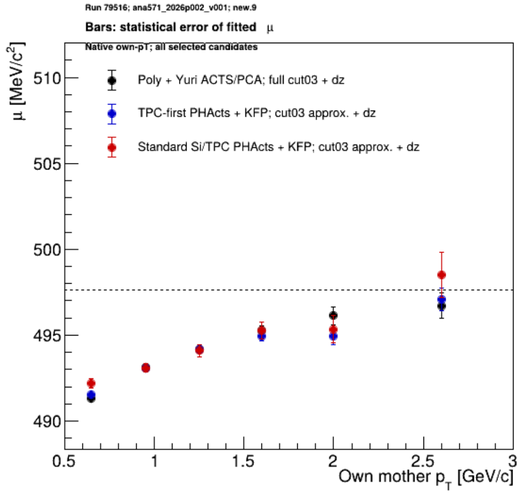
Test Yuri's PR (1)

➔ Yuri's PR: https://github.com/sPHENIX-Collaboration/coresoftware/pull/4503 including taubin fix and crossing time period fix

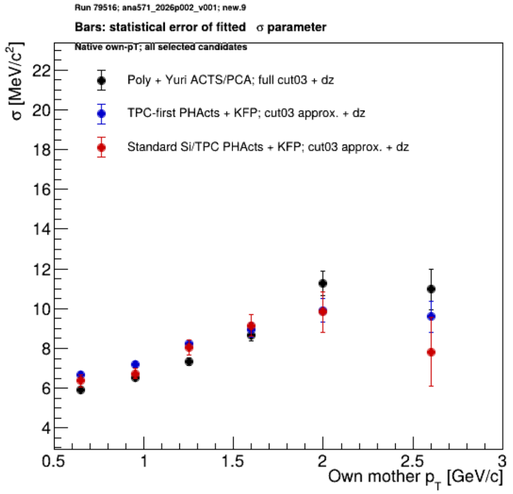
➔ I compiled local coresoftware with Yuri's PR changes, and rerun Kshort reconstruction



Gaussian mean



Gaussian sigma

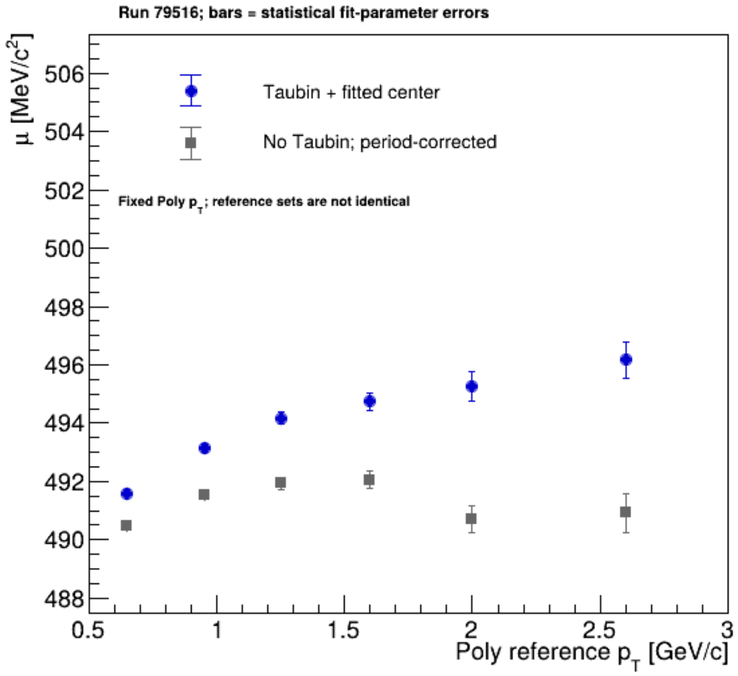


Black: Poly seed + Yuri's ACTS + PCA Kshort reco (reference)
Blue: Poly seed + TPC-only PHActs fit + KFP
Red: Poly seed + standard PHActs fit + KFP

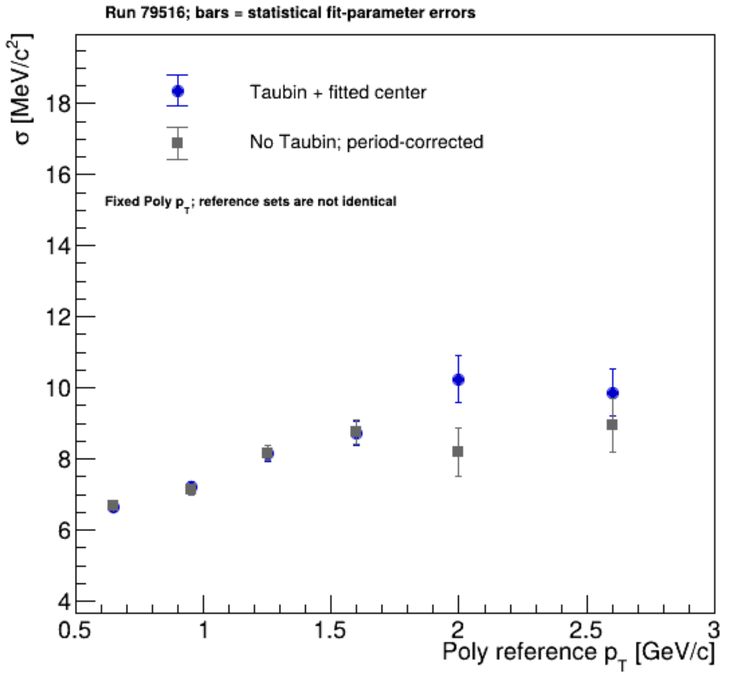
Peak position and resolution are consistent between three methods
TPC-only PHActs and Yuri's method give similar signal yields
Standard PHActs fit reconstruct less Kshort due to silicon-tpc matching

Test Yuri's PR (2)

Gaussian mean



Gaussian sigma

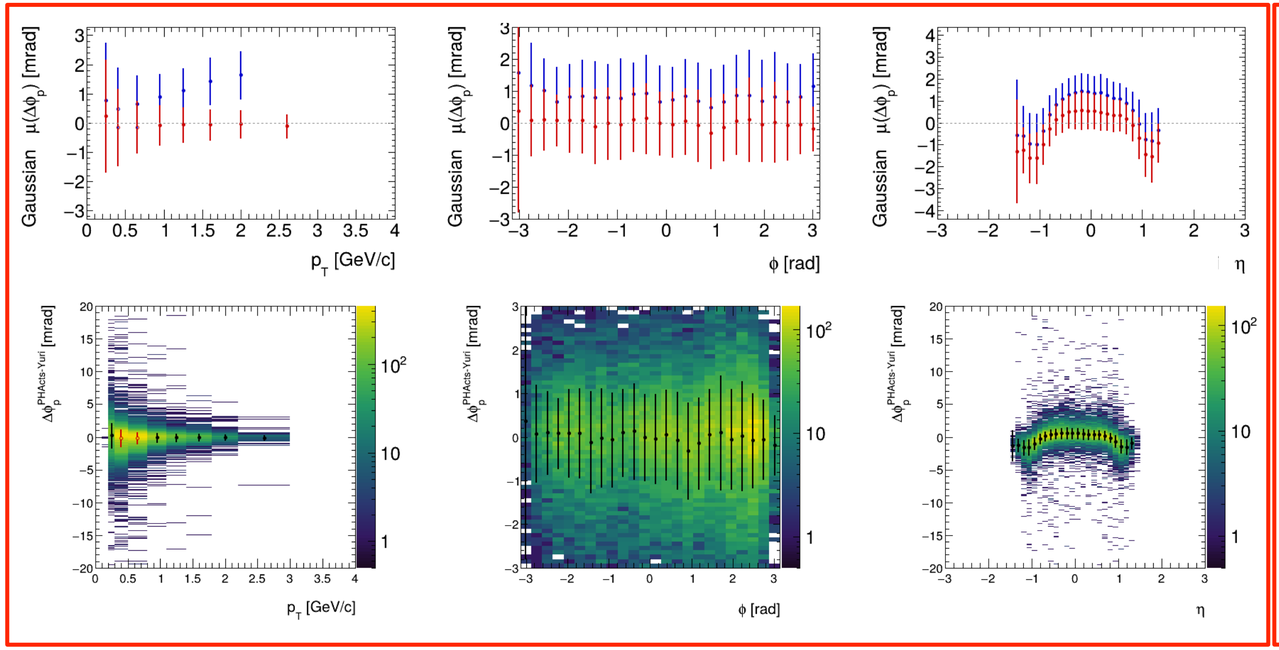


Blue: TPC-only PHActs fit before taubin fix

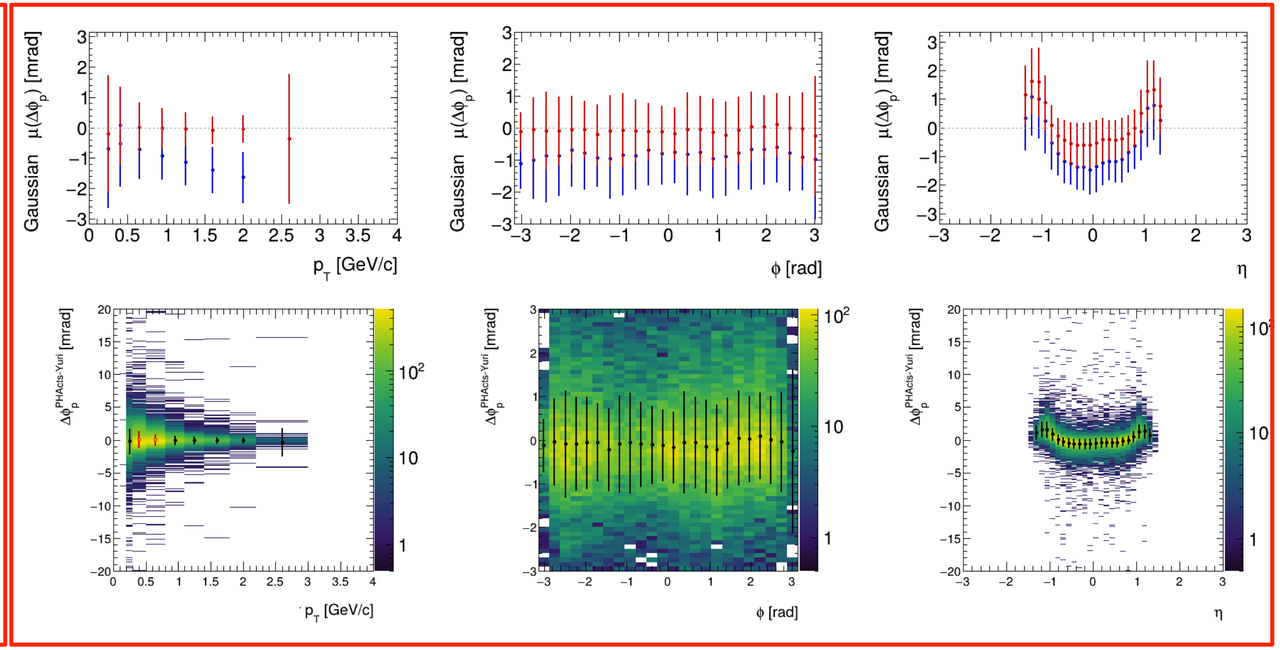
Gray: TPC-only PHActs fit after taubin fix

Test Yuri's PR (3)

Positive



Negative



- Delta-phi pT-dependent trend disappear
- Delta-phi phi-dependence shift disappear
- Delta-phi eta-dependent shape exists

Blue: before taubin fix
Red: after taubin fix

Conclusion

- ➔ TPC-only track crossing assignment in PHActs fit solve Kshort yields problem
- ➔ Unifying crossing time period solves delta-z residual between poly seed and PHActs track
- ➔ Taubin fit solve track momentum bias and Kshort mass shift in large pT region
- ➔ Track momentum bias and Kshort shift in low pT region is due to energy loss in silicon, including silicon clusters can solve it in principle
- ➔ Improved silicon-TPC alignment is needed

Thank you for your attention!

Backup

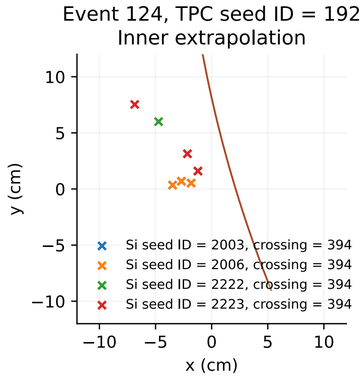
Yuri's cut03

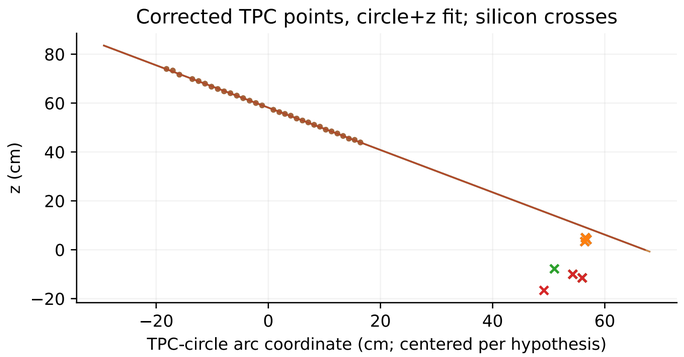
- ➔ both daughters: pT > 0.20 GeV/c
- ➔ decay radius R > 2.0 cm
- ➔ | alpha | < 0.99
- ➔ Sailor cut: phi+ - phi- >= 0.8 - 0.4*min(pT(V0), 2.0)
- ➔ crossing 0 is removed for either daughter
- ➔ pion-hypothesis dE/dx < 400
- ➔ | pca_z | < 15 cm
- ➔ | Delta PCA_z | < 0.50 cm
- ➔ | pairDCA | < 2.0 cm
- ➔ DIRA > 0.85
- ➔ quality < 15
- ➔ npoints > 30

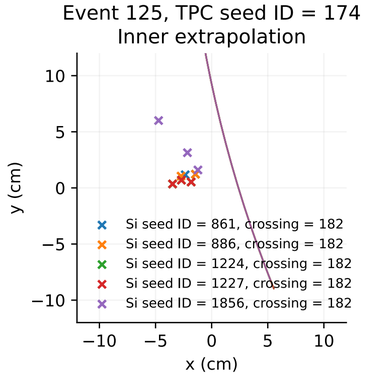
Cut03 definition

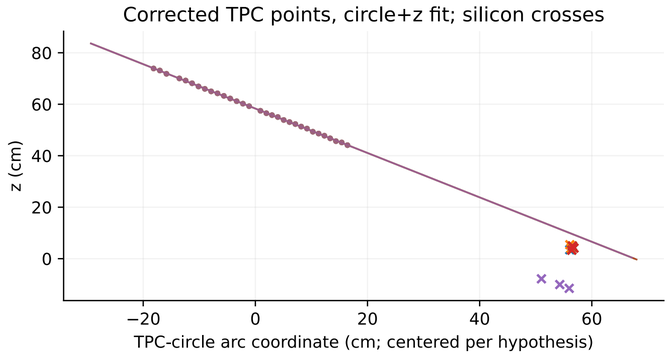
- For clarity, the variables used in the selections are:
- z_vtx
  - z position of the reconstructed V0 decay vertex.
- Delta z_vtx
  - |pca1_z - pca2_z|, i.e. the difference between the two daughter-track PCA z positions.
- R_vtx (decay radius)
  - transverse distance between the reconstructed V0 decay vertex and the beam position:
  - R_vtx = sqrt((x_vtx - x_beam)^2 + (y_vtx - y_beam)^2).
- pairDCA
  - distance-of-closest-approach quantity for the two daughter tracks. The selection is applied to |pairDCA|.
- DIRA
  - cosine of the angle between the V0 momentum and the flight vector from the beam position to the reconstructed V0 vertex.
  - DIRA -> 1 means that the reconstructed V0 momentum points along its flight direction.
- alpha
  - Armenteros-Podolanski alpha variable stored for the V0 candidate. The selection uses |alpha|.
- quality
  - track-fit quality. For the pair selection, the cut must be satisfied by both daughter tracks (the code uses the larger of the two quality values).
- npoints
  - number of track points/hits used for the track. The quoted requirement must be satisfied by both daughters (the code uses the smaller of the two npoints values).
- Sailor cut / Delta phi
  - Delta phi = phi+ - phi-, where phi+ and phi- are the azimuthal angles of the positive and negative daughter tracks.
  - The requirement is: Delta phi >= 0.8 - 0.4*min(pT(V0), 2.0).

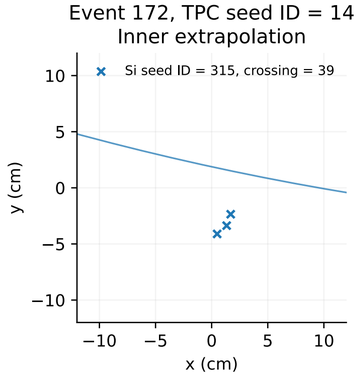
Event displays

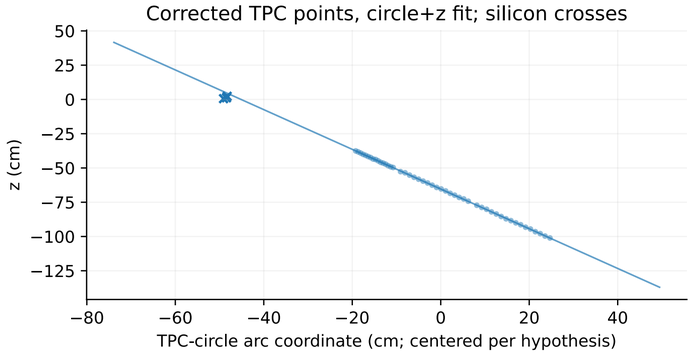












Momentum magnitude and angle test

